Biodivers Conserv (2009) 18:765–775
DOI 10.1007/s10531-008-9436-y

ORIGINAL PAPER

Conservation management for the past, present and future

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Received: 17 April 2008 / Accepted: 26 June 2008 / Published online: 16 July 2008

Abstract Conservation managers are in the unenviable position of trying to conserve and restore biodiversity, without having a definitive timeframe to restore it to. Currently, managers around the world focus on various timeframes from recent to historical, but without a definitive target, countless conservation problems arise. Managers need to determine what constitutes a native species, which species to reintroduce, whether selective breeding should be implemented to resurrect supposedly extinct organisms, targets on population levels, whether assisted migration should be employed when climate change alters the environmental envelope of a species surrounded by human-altered landscapes, and how to manage for stochasticity and evolutionary processes. Without having definitive goals to target, these issues are difficult/impossible to address. It is only by discussing these important issues that some consensus will be attained that allow us to stop responding to crises and start predicting the future of biodiversity and plan and respond accordingly.

Keywords Conservation management · Conservation benchmarks · Restoration · Reintroduction · Extinction · Introduced species

Introduction

Conservation managers are tasked with conserving biodiversity in the area they manage. Ostensibly, this seems an easy task—promoting ecological features that assist rare species

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to increase and those that keep potentially over-abundant or pest species in check. Yet in numerous conservation areas, the species that once occurred have gone extinct, and often have been replaced by others. Furthermore, today's conservation areas are generally small, isolated remnants in a sea of transformed habitat (Saunders et al. 1991) and therefore require human intervention to avoid inbreeding so that fundamental ecosystem processes can occur.

To achieve this, conservation managers are beginning to utilise reintroduction programmes to return ecological assemblages to a previous state. For example, wolves *Canis lupus* have been reintroduced into the USA's Yellowstone National Park (Smith 2006), lynx *Lynx lynx* have been returned to the Swiss Alps (Breitenmoser 1998) and large predators have been returned to South Africa's Eastern Cape Province (Hayward et al. 2007). Similarly, the Torreya Guardians are trying to save the 1,000 surviving individuals of the Florida torreya *Torreya taxifolia* from extinction by assisting the species disperse past unfavourable areas that are restricting natural range expansion caused by climate change (McLachlan et al. 2007).

Alternatively, conservation managers may utilise predator eradication programmes to rid their reserve of unwanted pests or overabundant indigenous species. New Zealanders have developed expertise at eradicating many types of introduced mammals (O'Connor and Matthews 1999) in the hope of protecting their endangered birds and reptiles.

Restoration timeframe targets

Recently, there has been debate (Caro 2007) following the proposal to 're-wild' North America with ecologically equivalent species to those driven extinct in the Pleistocene (Donlan et al. 2005). Some experts believe humans have an ethical responsibility to repair the damage our over exploitation caused while simultaneously restoring ecological and evolutionary potential (Donlan et al. 2005), however others contend that using exotic species will cause more problems and recommend restricting efforts to threatened biodiversity in-situ (Rubenstein et al. 2006). Similar projects are occurring in the Russian Far-East (Zimov 2005).

The fundamental question this debate has highlighted is what is the baseline ecological environment or benchmark that we should aim for in restoration attempts? Essentially there are five main timeframes that conservation managers can aim toward: (1) employment date of the current reserve manager; (2) reserve proclamation date; (3) pre-European levels; (4) pre-agricultural revolution levels; or (5) pre-human levels. This question is not a new one, but the answers will have a profound effect on the conservation of biodiversity (Flannery 1994; Macdonald 2001), particularly in light of changing climatic parameters and their effect on the habitats available to wildlife within the static boundaries of reserves.

To manage biodiversity to levels at the time of the managers employment date would generally be maintaining the *status quo*. This may be fine in unaltered ecosystems but on most of the planet, particularly in developed nations, conservation managers are striving for ecosystem restoration. Furthermore, the rapid increase in human overpopulation means few areas are free from human disturbance. Nonetheless, the reintroduction of tigers *Panthera tigris* to Sariska in India may be an example of this given the species was only recently driven extinct there by human activities (Johnsingh and Goyal 2005).

Managing biodiversity to the levels of the reserve's proclamation is likely to be a backward step given that the impetus for conserving the land was often the realisation that biodiversity had declined to low levels. The Sabi Game Reserve, predecessor of the Kruger National

Park, was proclaimed after South Africa's lowveld wildlife had been reduced to low numbers by intensive hunting (Carruthers 1995). In this case, most wildlife restocked the reserve naturally (Carruthers 1995), although Lichtenstein's hartebeest *Sigmoceros lichtensteinii* and black *Diceros bicornis* and white rhinoceros *Ceratotherium simum* were reintroduced. Given Europeans have coexisted with wildlife in Europe for hundreds of thousands of years, this may be an appropriate timeframe for this continent. The ecological recovery of European bison *Bison bonasus* in Poland's Białowieża Primeval Forest is an example of this.

The date of European, agricultural revolution or human arrival may serve as better conservation goals outside Europe and Africa given the generally dire results for biodiversity of their arrival (Flannery 1994; Diamond 1997). Which timeframe to manage for probably depends on the history of coevolution of humans and biodiversity on the continent in question, the levels of biodiversity surviving after these new waves of arrivals, the processes threatening their conservation and cultural factors.

Exploration by Europeans saw a modern spate of extinctions driven in part by modern technology that rapidly altered habitats and killed wildlife, such as the blue antelope *Hippotragus leucophaeus* (Smithers 1983). Managing for this timeframe is essentially what North American conservation managers are presently doing with their 1492 conservation benchmark (Caro 2007).

The agricultural revolution (10,000 years before present), where domesticated plants and animals afforded humans the opportunity to live beyond the natural carrying capacity of their environment, is another timeframe to aim for. Human populations were no longer limited by natural food resources, so their existence in permanent settlements meant they could locally exterminate wildlife from the vicinity of their settlements either directly or by taking the most productive lands which provided critical habitats for locally restricted or specialised plants and animals (Diamond 1997). The extinction of the moas in New Zealand may be an example of post-agricultural revolution extinctions as the Maori transported domesticated species with them (Flannery 1994).

Restoring ecological communities to pre-modern human colonist levels may be an ideal situation for sites outside Africa and Eurasia given the wave of extinctions linked to human arrival at a site in the Americas and Australia (Flannery 1994). Given the list of extinct species includes many evolutionarily distinctive taxa, this may be an unachievable goal. Other close relatives of many of these extinct species do persist elsewhere and it has been suggested that these be used as ecologically equivalent species to restore ecosystem functioning (Donlan et al. 2005).

Aiming for the latter three goals would yield substantial ecological benefits. Which to aim for is a value judgement and depends on the levels of biodiversity remaining to use in restocking or our understanding of the ecological situation historically or prehistorically.

Quandaries of restoration timeframe targets

Native species

Quandries raised by this time frame issue for conservation management are countless. How long does a species have to be resident before being naturalised (Macdonald 2001) and managed as part of the indigenous biodiversity? For example, should the kiore *Rattus exulans* be considered a native New Zealander given that it arrived with humans within the last 1,000 years (Flannery 1994)? While the humans probably brought about the demise of the megafauna, the kiore proceeded to eradicate smaller species like frogs, the tuatara *Sphenodon punctatus* and small birds (Flannery 1994). But the species has been in New Zealand for as long as people who consider themselves Aotearoans (Maori for New Zealander) have.

It seems inappropriate to exclude humans from consideration as natural parts of the biota given we evolved alongside wildlife in most places. For the length of human existence we have been an integral part of Africa's ecosystems, for millions years we have existed in Eurasia, for over 40,000 years in Australia, 12,000 years in the Americas and 1,000–800 years in New Zealand (Flannery 1994). The only place where we are truly recent arrivals is Antarctica. Indeed Antarctica is probably the only area where biodiversity can still be managed to pre-human levels. If people can be considered 'natives' after 1,000 years of habitation, then so surely can other species. On that basis, the kiore is a native and can avoid eradication in conservation management programmes.

The dingo *Canis lupus dingo* has been in Australia for 4,500 years so it could also be considered a 'native'. During its time in Australia, it has been linked to the extinction of the thylacine *Thylacinus cynocephalus* on the mainland (Flannery 1994).

Designating naturalised native species probably should relate to the costs and benefits these old invaders bring to the land we must now manage for conservation. The kiore is thought to have caused the extinction of several species and is currently the major threat to New Zealand's endangered parrot, the kakapo *Strigops habroptilus* (Clout and Craig 1995). While we will never know for sure what the cause was, the modern success of introduced placental mesocarnivores in Australia, which evolved in competition with larger carnivores, compared to the declining native marsupial ones suggests the dingo was intimately involved. In addition, today's dingo is a far cry from the species that occurred prior to the arrival of Europeans to Australia given that hybridisation with domestic pets has rendered them virtually feral dogs (Wilton 2001). What then is the value of managing an Australian national park with the conservation of the dingo in mind? Managers of the Epping Forest National Park have started eradicating dingoes because they kill some of the hundred or so northern hairy-nosed wombats *Lasiorhinus krefftii* that survive on the planet. While managers could simply reduce densities of these damaging 'natives', given the damage introduced placental predators have inflicted on Australia's decimated 'native' wildlife, it is becoming more apparent that the only chance the majority of species have is for the eradication of all placental predators, from conservation reserves at least, if not the country as a whole. In addition, such an action would surely safeguard Tasmania which currently acts as an 'ark' for countless Australian species. The same logic applies to kiore in New Zealand.

Questions of reintroduction

The reintroduction of wolves to Yellowstone, lynx to the Swiss Alps and large predators to the Eastern Cape made sense because it restored the ecological processes to these sites where predators had recently gone extinct at the hand of man, thereby reducing the future amount of conservation management required there. The reintroduction of white rhinoceros *Ceratotherium simum* to Uganda makes similar sense. They only went extinct 20 years ago due to the inability of Ugandan managers to conserve them under the onslaught of poaching. Operation Phoenix is the name of the largest wildlife reintroduction programme ever attempted, where more than 8,000 animals were returned to South Africa's Madikwe Game Reserve in the 1990s (Hofmeyr et al. 2003). Again this makes sense as each species occurred there before intensive agriculture took over the area. A point in favour of Australia's dingo is that it may perform valuable management of potentially overabundant species and mesopredator suppression of cats *Felis catus* and foxes *Vulpes vulpes* that would otherwise require human management.

Why, therefore, have Australian conservation managers taken so long to reintroduce the eastern quoll *Dasyurus viverrinus* to the mainland given they went extinct there over 40 years ago? We can only assume that they do not believe the agent of the quoll's decline has been removed and, despite the ability to fence nature reserves and eradicate introduced predators (e.g. Western Australia's Dryandra Nature Reserve), they lack the will to do so (Richards and Short 2003; Friend and Beecham 2004).

Tasmanian devils *Sarcophilus harrisi* thrive in Tasmania in the absence of placental predators and competitors, but is there justification for reintroducing them to the mainland given that they only went extinct there 450 years ago? By replacing dingoes/dogs with Tasmanian devils, conservation managers may achieve their ultimate goal of conserving biodiversity more successfully than otherwise. Information will be needed to determine if there is a sufficient prey base, following almost two centuries of predation by introduced European red foxes *Vulpes vulpes* and cats *Felis catus*, to support a predator like the devil.

Researchers at the Australian Museum attempted to extract DNA from a thylacine museum specimen in the hope of cloning them (Archer et al. 2002). If this ever proved successful, conservation manager would have to contemplate reintroducing a population of thylacine in the reserve they control. They'd probably have to eradicate dingoes/dogs from the reserve beforehand to remove the original agent of decline.

Conservation managers are understandably alarmed as the American mink *Mustela vison* wades through Europe decimating populations of its native, European congener *M. lutreola* (Macdonald 2001). Yet if a population of lion *Panthera leo* suddenly sprang up and decimated red deer *Cervus elaphus,* red foxes and badgers *Meles meles*, would that be cause for concern given that the lion only went extinct in Europe some 2,000 years ago. It is unlikely that conservation managers should be planning such reintroductions as they seem bound to fail unless the agent of the lion's decline has been removed. Given that this was probably human-induced via direct persecution, a reduction in prey base and habitat alteration, it would appear that the agents are still with us.

The situation in North America is somewhat simpler. If the Pleistocene megafauna were to be replaced, North Americans could import zebras, elephants and lions from Africa, and spectacled bears, peccarys, camelids and tapirs from South America (Flannery 1994; Donlan et al. 2005). By that rationale, New Zealanders should introduce ostrich *Struthio camelus*, emu *Dromaius novaehollandiae*, cassowary *Casuarius casuarius*, or rhea *Rhea americana* to fill the vacant niche left by the moa. Similarly, Australians should import komodo dragons *Varanus komodoensis* given that they are near extant relatives of the extinct giant predatory varanid *Megalania* (Flannery 1994) and then selectively breed them for gigantism. Selective breeding could be used to reverse the trend in dwarfism in countless animals following selective, prehistoric human hunting (Flannery 1994)?

Selective breeding

Selective breeding for conservation purposes to mimic evolution or natural selection in order to recreate extinct species seems like too much human intervention. Yet South African conservation managers have already initiated such management practices. They are successfully selectively breeding stripeless plains zebra *Equus burchelli* to resemble the extinct quagga's *E. quagga* phenotype at several sites including the Karoo National Park. The quagga has recently been found to be a mere phenotypic variant of the plains zebra (Hartley 1988).

Management of population density targets

Herbivore overpopulation also requires conservation management attention. The burgeoning elephant *Loxodonta africana* population in South Africa's Kruger National Park has effectively doubled from 7,000 in the past decade since culling ceased (Whyte et al. 2003). Even at 7,000 elephants they were detrimentally affecting biodiversity but, perhaps through fear of animal rights groups, have opted for a 'zones of varying impact' policy. On this basis, the scale of damage caused by the 150,000 elephants in northern Botswana, where carrying capacity is thought to be around 60,000, could potentially be large (Kerley et al. 2007).

Yet to what density should conservation managers manage the elephant population, given there were almost no elephants in Kruger when the Sabi Game Reserve was gazetted in the late nineteenth century (Carruthers 1995)? Managing the Kruger elephants with an aim of a zero density would be wrong given that prior to its proclamation, elephants were frequently hunted in the region. But at what density should elephants be managed to given human predation has probably occurred on elephants for as long as our species have co-existed. Similar issues occur in managing deer in the Holarctic.

Assisted range expansion

What this series of eclectic conservation conundrums is highlighting, is how can we manage biodiversity for the future? Climate change is a reality and human-induced habitat change has already happened. If a species' preferred habitat occurs in a conservation reserve, should it be translocated into that reserve, even if there are no prior records of it in the area?

White rhinoceros flourish in the agriculturally-transformed grasslands of South Africa's Eastern Cape, such as Shamwari and Dwesa Game Reserves, where they are largely free from poaching. Yet there are no historical records of their existence in this region as such grasslands originally only covered tiny areas of the province. Today, human-induced habitat change has produced large areas of available habitat for white rhinos, yet government policy stipulates that they cannot be introduced to the region. In the absence of fences, could white rhino have moved into this transformed landscape of their own volition, in the same way as eastern grey kangaroos *Macropus fuliginosus* have in Australia where human waterpoints allowed them access that could not be impeded by fences? Knowledge of the dispersal capability of white rhino would enable us to determine if colonising individuals could move between isolated patches of suitable habitat in the absence of fences (and other human created barriers) to found a population in previously unoccupied areas. So what is a conservation manager to do if it is believed that white rhino could now colonise the reserve?

White rhinoceros could also perform valuable management actions there. In the Eastern Cape, the succulent, drought- and fire-resistant thicket vegetation is unlikely to recover from agricultural transformation followed by browsing from elephant and kudu *Tragelaphus strepsiceros* amongst others (Sigwela 2004). Consequently the grasslands are likely to remain, but because they lack sufficient bulk grazers, such as white rhinos, these grasslands attain climax levels, senesce and reduce productivity and thereby become genuine fire hazards in an area historically considered immune to fire. The effect of fire on the soils is likely to be devastating. Elsewhere, savanna grasslands are managed by conservation managers via the use of fire to maximise productivity, as they have been for thousands of years by humans (Jones 1969). This is not an option in the Thicket biome. Some management practice to reduce the build up of fuel loads and therefore the risk of fire is required, and a bulk grazer, such as the white rhinoceros could be introduced to perform this function while reducing the need for humans to intervene. This would also perform a secondary function of protecting the white rhino from extinction. In essence, this is managing for new ecosystems that have evolved and is a future-oriented management approach rather than seeking historical benchmarks.

The conservation managers of Kruger National Park are contending whether to manage the environment to ensure the last 30 roan antelope *Hippotragus equinus* survive into the future. This would entail closing numerous waterpoints that maintain artificially high wildlife densities (Harrington et al. 1999) which itself is driven by the interests of maximising tourism. Waterpoint closure is occurring, but conservation managers could alternatively argue that Kruger is at the periphery of the roan's range and its imminent extinction is a natural phenomenon, where recolonisation would have originally occurred during good/bad climatic conditions. Perhaps this is the future of roan management in Kruger-regular reintroduction/supplementation in years with climatic conditions likely to suit them and localised extinction outside these times.

Disease may have wiped out the last of the Serengeti's African wild dogs *Lycaon pictus*, but it seems most likely that competition from larger predators or a reduction in prey base was the agent of their decline (Creel and Creel 1996). Do we reintroduce dogs given that the removal of disease has increased prey densities to levels that support unprecedented densities of lion and spotted hyaena (Hanby and Bygott 1979). It may be necessary for Serengeti managers to limit blue wildebeest *Connochaetes taurinus* and zebra *Equus burchelli* numbers to recreate the situation that existed prior to the arrival of modern veterinary medicine that allowed their populations to expand so substantially (Sinclair 1979). Such actions may aid the cheetah *Acinonyx jubatus* as well by creating more areas of low wildlife densities that provide them with refuge from competition (Durant 1998), however the likely reduction in lion abundance would conflict with the goals of tourism management. Assisted migration is already occurring (Fox 2007) and, given the disturbance to intermediate habitats of 1,870 Mexican species that require range expansion due to climate change (Peterson et al. 2002), it seems increasingly necessary.

Evolutionary processes

Conversely, what about managing biodiversity with future evolutionary processes in mind? Ideally, conservation areas would be designed to allow future evolutionary processes to occur on the biodiversity housed within. For example, South Africa's Addo Elephant National Park will eventually extend from the coast inland for 200 km through six of the country's seven biomes, such that its 300,000 ha will potentially allow species to migrate or evolve to cope with the threats of climate change (Kerley and Boshoff 1997). Yet reserves this size are the exception and those that are large rarely traverse several biomes (e.g. Kruger and the Serengeti).

Management options

The majority of conservation managers control small reserves, that are surrounded by fences or uninhabitable land, and so face difficulties managing for the future given that they are often too small to support viable populations of larger species? South African conservation managers in such situations have decided to manage African wild dogs as a metapopulation by regular translocations between reserves acting as a replacement of natural dispersal events (Davies-Mostert et al. 2008). This is managing to a time period prior to the alteration of the intermediate areas of habitat required to support adequate wildlife which in turn supports wild dogs. Similar strategies are probably available to the Nepalese managers of Royal Chitwan National Park in protecting their tigers *Panthera tigris*. Returning water buffalo *Bubalus bubalis* and other locally extinct potential prey species might increase the number of tigers, but nothing short of removing the humans inhabiting the periphery of the reserve is going to make it large enough to support a viable population of tigers (Sunquist et al. 1987). Connective corridors are being planned which will create a Terai Arc tiger landscape that may be large enough to support a viable population (Dinerstein et al. 2007).

Fire

Fire is another conservation management activity that needs to be seen in the light of the time period that a reserve is managed to. Fire history in Australia has altered dramatically since the Pleistocene and even more dramatically following the arrival of each wave of human immigrants. Prehistoric fire regimes in Australia were characterised by infrequent, low-intensity fires ignited by natural causes (lightening; branches rubbing together in windy conditions) due to the low fuel loads available following browsing by megaherbivores (Flannery 1994). Then, 60,000 years ago fires became more frequent and fire-sensitive plants were replaced by fire-tolerant species such as *Eucalyptus*. This has been interpreted as stemming from the arrival of the first humans to Australia and the extinction of the megafauna there (Flannery 1994). Aboriginal people then set about burning the land to promote flora and fauna useful to them (Jones 1969), for example at a frequency of every three to four years in south-western Australia (Hayward et al. 2005). This fire regime existed for tens of thousands of years until Europeans arrived. Initially this second wave of immigrants promoted a fire-exclusion policy and, in much the same way as such policies led to bush encroachment in sites where megaherbivores survive, the vegetation structure and floristics were altered (Flannery 1994).

After all this variation in fire frequencies and intensities, it is difficult for conservation managers in Australia to use fire to manage the environment of a reserve. Fire is clearly a fundamental factor in Australian ecosystems. I would suggest that fire management to pre-human regimes would be wrong given the length of time the Australian biota has had to evolve adaptations to the fire regimes imposed by Aboriginals. Similarly, managing fire to that imposed by early European colonists is unlikely to be beneficial to biodiversity given the short time frame that it has occurred. Hence, trying to replicate Aboriginal burning regimes of particular areas should be sought by conservation managers, and this is occurring (Flannery 1994).

Conclusions

The USA is unofficially and arbitrarily aiming to restore biodiversity to 1,492 (European colonisation) levels (Caro 2007), although there has been discussion of restoring biodiversity to human colonisation periods (Donlan et al. 2005). Europe has always been occupied by Europeans, however the existing conservation paradigm seems to be management for coexistence between people and extant fauna (Linnell et al. 2005). The UK seems to be aiming to restore cultural landscapes of the pre-industrial intensification period and suggestions to reintroduce Eurasian lynx *Lynx lynx* have not been positively met in some quarters

(Hetherington 2006; Hetherington and Gorman 2007). Australia is lagging behind as it is still trying to halt the extinction process, although private organisations are beginning to manage biodiversity to pre-European colonisation targets. New Zealanders are aiming for pre-human targets, although resurrecting the moas may prove difficult. Africa has, perhaps, the easiest goal with fewest extinctions and permanent coexistence of humans and animals, but conservation managers there are still proactively righting the wrongs of colonists, while faced with the massive threat of expanding populations.

So where to from here? Conservation managers should manage their land with as much knowledge as can be acquired and hence research is fundamental. As extrapolating the ecology of Africa's carnivores based on studies from the atypical Serengeti plains (Mills et al. 2004) or for macropods between island and mainland populations (Hayward et al. 2003; Hayward et al. 2004), has been shown to be unfounded, so too is extrapolating about the ecology of species between virtually any region or ecosystem that potentially differ from that of the rest of a species' range.

Secondly, ecosystems are dynamic things that are rarely at equilibrium but are rather in a constant state of flux. Perhaps research into the ability of a species to colonise an area based on dispersal rates, distance and intervening habitat (both original and whatever is remaining today) would assist in determining the likelihood of a species self-colonising a site. With fences probably inhibiting this nowadays, conservation managers should subsequently assist with such occurrences if they are deemed possible.

With respect to newer invaders, I suspect a conservation cost-benefit analysis would be beneficial. Does the presence of a human-assisted invader benefit or hinder the area's biodiversity conservation? Do these species provide a fundamental ecosystem service that cannot be performed by a 'truer native' or do they threaten the conservation of other species? Essentially, the native/indigenous paradigm may not be overly helpful in determining the need for conservation action and more emphasis should be placed on the impacts of species.

There are many ways of setting population target levels for biodiversity conservation, but most target a period when humans had less impact on biodiversity than today (Sanderson 2006). The arbitrary benchmarks of manager appointment date and reserve proclamation date are options that are often applied in preference to the other benchmarks that have some ecological basis. These arbitrary, administrative benchmarks easily suffer from the shifting baseline syndrome where a manager believes the present ecological situation has always occurred (Pauly 1995). Where ecosystems have been irrevocably damaged and new stable-states have evolved, consideration may be given to managing for the future rather than some arbitrary, historical benchmark. Irrespectively, it is a value choice as to which level we manage to.

Innovative steps are required if biodiversity is to be conserved in the face of climate change, human overpopulation and introduced species. Conservation managers have been given a huge responsibility and they need to know how to address issues such as those raised here. I think conservation areas should be managed to a timeframe as far back as possible or to a period where native species have evolved mechanisms to exist. However, it is only via discussion, debate and research that these important answers will be forthcoming. Are we going to continue responding to crises by way of environmental triage or start predicting the future and then plan and respond accordingly?

Acknowledgements This paper was improved with reviews by G. Hayward, B. Russell, and B. Schulte. Markus Hofmeyr provided information on the reintroductions to Kruger and distributed this manuscript to several African regional conservation managers whose positive responses ensured my enthusiasm for this project did not wain. Gina Dawson conducted field work sponsored by Nelson Mandela Metropolitan University, SAN Parks, Budget Rent-a-Car, Continental Tyres, Leica, C.R. Kennedy and Eveready Batterys.

I was funded by an NRF Post-doctoral Research Fellowship and a Marie Curie Transfer of Knowledge Fellowship project-BIORESC MTKD-CT-2005-029957-financed by the 6th Framework Programme of the European Union.

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